

FINAL REPORT

WATER IMPACT SHOCK TEST SYSTEM

Contract No.: NAS8-31945

SECO-DYN INC./Pomona, California

(NASA-CR-150473) WATER IMPACT SHOCK TEST
SYSTEM Final Report (SECO-DYN, Inc.,
Pomona, Calif.) 85 p HC A05/MF A01 CSCL 200

N78-13365

G3/34 Unclas
55046



Prepared For: NASA
George C. Marshall Space Flight Center
Huntsville, Alabama

Prepared By: SECO-DYN INC.
158 San Lorenzo Street
Pomona, California 91766

Subject: Final Report
Contract No.: NAS8-31945
Water Impact Shock Test System

Date: November 10, 1977

Table of Contents

Section I : Introduction	Page 1
Section II : Principles of Operation	6
Section III: Operating Procedures	27
Section IV: Maintenance	35
Section V : Assembly Procedures	41
Section VI : Parts List and Recommended Spare Parts	63
Section VII: Performance Determination and Analysis	74

Section I: Introduction

The basic objective involved was to design, manufacture and install a shock test system which, in part, would have the ability to subject test articles weighing up to 1,000 pounds to both half sine and/or full sine pulses having peak levels of up to 50 G's with half sine pulse durations of 100 milliseconds or full sine period duration of 200 milliseconds.

The tolerances associated with the aforementioned pulses was $\pm 20\%$ and -10% for the peak levels and $\pm 10\%$ for the pulse durations.

The subject shock test system was to be capable of accepting test article sizes of up to 4 feet by 4 feet mounting surface by 4 feet in length.

When producing half sine or any "half wave" shock pulses the negative or deceleration level was to be no greater than 20% of the positive or acceleration level.

After considering various techniques employed for introducing shock environments and when considering the rather unusual requirement of producing full sine waves it

was decided that the best technique was to employ a horizontally oriented system wherein a special actuator assembly would impact the shock environment to a carriage to which the test article was attached. The actuator assembly must therefore have the ability to control both the initial positive acceleration environment plus control the immediately following negative deceleration environment.

The carriage is located on and guided by a track system such that when full (sine) wave tests are conducted the carriage is rigidly attached to the actuator output column so as to experience the full wave environment being effected by the actuator and when half (sine) wave tests are conducted the aforementioned attachment is removed and the actuator output column simply forces against the carriage to impact the positive acceleration environment. Following this acceleration environment the carriage separates from the actuator output column due to the fact that the deceleration level effected to the column is greater than effected to the carriage and the carriage travels along the guide track system. The carriage contains pneumatic operated friction brakes which are employed to decelerate the carriage within the track system allowable travel.

The actuator assembly; which has an overall length of 32 ft. 5 1/8 in.; employs high pressure gas of up to 2,000 psi acting over the aft surface of a piston; which has a diameter of 15.220 inches; to produce a positive output force. A fluid chamber is located forward of said piston with a specially shaped metering column and fluid orifice plate positioned such that the fluid pressure acting over the forward surface of the aforementioned piston can be controlled to thereby permit the net positive and negative output force to be controlled to produce the desired "full wave" shock pulse. The fluid employed is water.

The aforementioned pulse waveform controlling metering column is designed to produce a specific "full wave" shock pulse. The gas pressure employed can be increased and decreased to thereby alter the shock pulse produced. When the gas pressure is increased the shock levels will increase and the pulse duration will decrease. When the gas pressure is decreased the shock levels will decrease and the pulse duration will increase. It is found that a single metering column can produce a range of shock pulses while still staying within the allowable shock level and

duration tolerances previously stated. When it is desired to produce shock pulses which have a different waveform and/or have levels and durations which are beyond the aforementioned range then another metering column must be installed in the actuator assembly which is designed for the desired pulse(s).

As previously stated, when producing half sine and/or half wave shock pulses the actuator assembly introduces the required acceleration shock pulse. The carriage assembly then separates from the actuator column and moves along the track system. The carriage and test article deceleration is accomplished by pneumatic operated friction brakes located on the carriage which force automotive type brake lining pads against the track surfaces. This pneumatic brake pressure is introduced and the brakes are applied prior to initiation of the shock pulse. The pressure level employed controls the deceleration or negative level effected to the carriage and test article. The overall length of the track system is 50 feet. The total useable track distance is approximately 41 feet.

A steel housing is located at the end of the track opposite the actuator assembly and said housing is filled

with foam blocks. The total depth of foam is 8 feet with 4 feet located in the track system and the balance of 4 feet located beyond the end of the track system. The purpose of this foam barrier is to safely stop the carriage and/or test article in the event that both the primary and redundant carriage brake systems fail.

The actuator assembly is attached to a forward mounting surface of a steel weldment reaction structure that is secured to two (2) "high load points" pads located within the building floor and foundation. This structure and its attachment is safely capable of transmitting and reacting the maximum output force capability of the acutaor assembly.

A control console is employed to allow the operator to perform all fundions required to operate and perform tests with the subject system.

Section II: Principles of Operation

The drawing number 611-4A presents the actuator assembly which is basically a three (3) chamber unit consisting of the 611-4-12 Rear Cylinder; the 611-4-28 Fluid Chamber Cylinder; and the 611-4-34 Forward Cylinder.

The 611-4-12 Rear Cylinder chamber is enclosed at the aft end by the 611-4-10 Rear Cover which is secured by socket head cap screws which pass through the 611-4-11 Rear Cylinder Flange and into the Rear Cover. The Rear Cylinder chamber is enclosed at the forward end by the 611-4-26 Orifice Plate and the "8 inch Valve" which initially confines the high pressure gas to the Rear Cylinder chamber by sealing the 8 inch diameter passageway contained within the Orifice Plate.

The moving element assembly of the "8 inch Valve" consists of the 611-4-22 Valve Piston; the 611-4-20 Valve Connecting Rod; the 611-4-25 Valve Flow Restrictor; the 611-4-17 Valve Seal Piston; and the 611-4-16 Valve Lock Nut. The basic manner of operation of the subject Valve is as follows:

1. Relatively low pressure gas, which is termed as "Valve Close Pressure", is introduced into the chamber between the 611-4-17 Valve Seal Piston and the 611-4-13 Valve Rear Cover which then forces the valve moving element assembly forward to "place" the Valve in its closed position.

This action causes the peripheral seal ring contoured on the 611-4-22 Valve Piston to engage the 611-4-26 Orifice Plate passageway and causes the face seal ring contained on the 611-4-17 Valve Seal Piston to make contact with the aft surface of the 611-4-18 Valve Orifice.

2. Relatively high fluid pressure is then effected, by means of an accumulator/solenoid valves assembly located in the control console, in the chamber between the 611-4-22 Valve Piston and the 611-4-17 Valve Seal Piston.

This fluid pressure acts over the aft surface of the 611-4-22 Valve Piston from the outer diameter of said Piston to the diameter of the 611-4-20 Valve Connecting Rod.

This fluid pressure also acts over the forward surface of the 611-4-17 Valve Seal Piston from the sealing point of the face seal ring to the diameter of the 611-4-20 Valve Connecting Rod.

The net fluid pressure force is a forward acting force which tends to help the valve in its closed position.

3. Due to the fact that the fluid pressure causes a valve closure force the low pressure Valve Close Pressure gas can and is exhausted.
4. Gas pressure, which is termed Valve Open Pressure, is introduced into the chamber between the 611-4-23 Separator Plate and the 611-4-22 Valve Piston.

This pressure causes a force which tends to open the valve and normally the ratio between the Valve Fluid Pressure and Valve Open Pressure should be 1.5 to 1 (i.e.: if the Valve Open Pressure is to be 500 psi then the Fluid Pressure employed should be 750 psi).

5. When it is desired to open the valve, a switch is depressed at the console which opens a solenoid valve so as to allow the fluid to flow into the console accumulator to thereby allow the valve moving element assembly to move toward an open position.

After slight motion has occurred the face seal ring on the 611-4-17 Valve Seal Piston breaks contact with the aft surface of the 611-4-18 Valve Orifice to thereby allow any remaining fluid pressure to act over equal areas of the 611-4-22 Valve Piston and the 611-4-17 Valve Seal Piston thereby causing a net zero force.

6. The Valve Open Pressure gas force then moves the valve to its open position which causes the peripheral seal ring on the 611-4-22 Valve Piston to be removed from the 611-4-26 Orifice Plate passageway thereby allowing the gas pressure contained in the Rear Cylinder chamber, which is termed Acceleration Pressure, to flow through the ports located in the 611-4-24 Valve Port Cylinder and through the Orifice Plate passageway to then act over the aft surface of the 611-4-27 Piston.

7. The purpose of the 611-4-25 Valve Flow Restrictor is to cause the initial valve opening phase to occur rather slowly by greatly restricting the flow of the fluid from the chamber forward of the 611-4-18 Valve Orifice to the chamber aft of the Valve Orifice for the first 1.25 inches of valve motion.

Following this phase the fluid flow area is greatly increased to thereby permit very rapid valve opening.

The necessity of this "two phase" valve opening action will be discussed further on in this section.

8. Deceleration of the valve moving element assembly is accomplished by the specially contoured "plug", located at the aft end of the 611-4-22 Valve Piston, entering the 611-4-18 Valve Orifice passageway to thereby produce a controlled fluid pressure force against the aft surface of the Valve Piston.

The approximate gas pressure volume of the Rear Cylinder chamber is 20,204 cubic inches.

The actuator assembly middle chamber is enclosed by the 611-4-28 Fluid Chamber Cylinder and is closed at the ends by the flanged attached 611-4-26 Orifice Plate at the aft end and by the flanged attached 611-4-30 Fluid Orifice Plate at the forward end. This chamber is filled with fluid; which is water with an appropriate amount of rust inhibitor.

The 611-4-27 Piston is connected to the 611-4-97 Separator Column by means of the 611-4-45 Piston Stud. The 611-4-96 Support Piston is flange connected to the Separator Column with socket head cap screws employed. The 611-4-95 Metering Column is male thread connected to the Support Piston at the aft end and male thread connected to the 611-4-32 Separator Piston at the forward end. The bore of the 611-4-28 Fluid Chamber Cylinder is 15.220 inches and is hard chrome plated.

When the "8 inch Valve" is opened the Acceleration Pressure gas is allowed to act over the aft surface of the 611-4-27 Piston to thereby produce a positive output force which when applied to a "free moving" mass will result in acceleration, velocity, and displacement be achieved.

The 611-4-95 Metering Column has a contour which is specially designed to permit a specific fluid flow area to occur at a given displacement and/or at a given point in time. The fluid pressure drop across the 611-4-30 Fluid Orifice Plate and therefore the fluid pressure acting on the forward surface of the 611-4-96 Support Piston is being controlled by the Metering Column establishing an effective fluid flow area at a given "piston" velocity. By one knowing the instantaneous gas pressure acting on the aft surface of the 611-4-27 Piston and by effecting a specific fluid pressure acting on the forward surface of the 611-4-96 Support Piston then the net output force can be controlled for both positive levels to apply acceleration and/or negative levels to apply deceleration.

The actuator forward chamber is enclosed by the 611-4-34 Forward Cylinder and is closed at the ends by the flange attached 611-4-30 Fluid Orifice Plate at the aft end and by the flange attached 611-4-40 Forward Cover at the forward end. The forward end of the 611-4-95 Metering Column is male thread connected to the 611-4-32 Separator Piston and the 611-4-42 Main Column is flanged connected to the forward surface of the 611-4-32 Separator

Piston. The 611-4-39 Bushing, located within the Forward Cover, is made from brass and is employed to guide the Main Column.

The Forward Cylinder chamber, in part, acts simply as a receiver to accept the fluid being displaced from the 611-4-28 Fluid Chamber Cylinder as the shock environment is being produced.

There are two (2) Relief Valves attached to the outer periphery of the Forward Cylinder at the extreme forward end of said chamber. These Relief Valves are employed to exhaust the atmospheric pressure gas located in the chamber forward of the 611-4-32 Separator Piston as said Piston is being displaced during the shock environment. It is found that for relatively long stroke shock pulses that when the subject chamber has an initial pressure of 14.7 psi that at the conclusion of said stroke the pressure will increase to several hundred psi and thereby this gas must be permitted to exhaust during the shock stroke.

When it is desired to move the actuator assembly moving elements to their initial retracted position relatively low pressure gas is introduced through the 611-4-40

Forward Cover and into the chamber forward of the 611-4-32 Separator Piston. At this time the same gas pressure is introduced into the 611-4-35 Exhaust Valve Cylinders to act on the aft surface of the 611-4-37 Valve Seal Piston to thereby force the face sealing ring, located on the forward surface of the Valve Seal Pistons, against the port sealing surface on the 611-4-34 Forward Cylinder. This action confines the aforementioned low pressure gas, termed Retract Pressure, to the forward chamber. The pneumatic control circuit associated with the Retract Pressure introduction is arranged to exhaust the subject gas pressure from only the two (2) 611-4-35 Exhaust Valve Cylinder chambers such that the pressure remaining in the Forward Cylinder chamber will force the 611-4-37 Valve Seal Pistons to an open position to thereby totally exhaust all Retract Pressure prior to conducting the tests and will result in the Relief Valves being in an open position so as to allow the gas in the Forward Cylinder chamber to be exhausted as Separator Piston displacement occurs.

Two (2) ports exist in the 611-4-34 Forward Cylinder at diametrically opposite locations. This cylinder should

be positioned so as to have one port at the top and one port at the bottom of the actuator assembly. These ports are employed to fill and purge the actuator assembly fluid chamber. The entire moving elements assembly should be moved fully outward so as to fully extend the Main Column by introducing low pressure gas behind the 611-4-27 Piston. The fluid (water) should be introduced through the bottom port and the gas should be removed through the top port. When all gas has been removed and a pure fluid stream discharges from the top port the chamber is filled and purged. The two ports should be shut-off and the moving elements assembly retracted by introduction of Retract Pressure.

Immediately prior to conducting a shock test the actuator assembly moving elements are positioned as shown by drawing number 611-4-A. At this time the fluid, contained between the 611-4-30 Fluid Orifice Plate and the 611-4-96 Support Piston, is at atmospheric pressure. When the "8 inch Valve" is opened and the Acceleration Pressure is allowed to act over the aft surface of the 611-4-27 Piston a net positive output force is attempted. However, at the initiation of the shock pulse the net output force

must start at zero so as to start at zero acceleration. Therefore the fluid chamber pressure must be increased to a level which will produce a force on the forward surface of the 611-4-96 Support Piston which equals the force on the aft surface of the 611-4-27 Piston. This is accomplished by the entire moving element assembly moving forward and due to the existence of the relatively long shoulder on the forward end of the 611-4-95 Metering Column the compressed fluid essentially is not permitted to discharge through the 611-4-30 Fluid Orifice Plate. Relative to specific figures the area of the 611-4-27 Piston aft surface is 181.844 square inches; the effective area of the 611-4-96 Support Piston forward surface is 120.01 square inches; and the approximate fluid volume is 11,500 cubic inches. With say 1,000 psi Acceleration Pressure applied to the aft surface of the 611-4-27 Piston a fluid pressure of 1515 psi must be effected to cause equal opposite forces. The fluid chamber must be "shortened" to achieve the above and the actual amount can be determined in the following manner:

$$E = \frac{\psi}{\epsilon}$$

E = bulk modulus of 300,000 psi

ψ = fluid pressure

ϵ = fluid chamber strain

$$\epsilon = \frac{1515}{300,000} = .00505 \text{ in./in.}$$

$$\Delta V \text{ (volume change)} = .00505 (11,500) = 58.075 \text{ cu. in.}$$

$$\text{Piston Displacement required} = \frac{58.075}{120.01} = \underline{\underline{.484}} \text{ inches}$$

This piston displacement and fluid chamber compression will occur immediately upon application of the Acceleration Pressure to the 611-4-27 Piston. It is desirable that this action occur over a sufficient time period so that a "pre-test shock" will not be imparted to the test article. It is for this reason that the 611-4-25 Valve Flow Restrictor exists within the "8 inch Valve" such that the initial valve opening phase occurs "slowly" while the fluid compression is being accomplished which is then followed by a rapid valve opening phase when producing the shock pulse.

The shock forces are transmitted through the 611-4-42 Main Column which contains the 611-4-41 Column Forward Flange. The 611-3 Column Guide assembly is attached to the forward end of the Main Column and is intended to support the static weight of the Main Column as outward motion occurs as well as to distribute the shock force over a relatively large area of the carriage aft surface. When conducting full (sine) wave shock pulses the actuator moving element assembly is rigidly attached to the carriage and

for such cases the Main Column could be directly connected to the carriage. However, for half (sine) wave shock pulses the actuator moving element assembly simply forces against the carriage and separation occurs at the initiation of the deceleration or negative phase with the carriage moving away from the actuator moving element assembly. For such tests the 611-3 Column Guide assembly is required and therefore is employed for all tests.

The "shoulder" existing at the output end of the 611-4-42 Main Column engages a "close-fitting" counterbore contained within the Column Guide aft surface and the 611-4-41 Column Forward Flange is connected, by means of cap screws, to the threaded insert bolt pattern existing at the Column Guide aft surface.

The Column Guide is instructed to "enclose" three sides of each Guide Track being the inside; top; and bottom surfaces. The 611-3-13 Guide Inserts are made from brass plate and are positioned within the appropriate Column Guide members so as to contact the aforementioned Guide Track surfaces with set screws "behind" each Guide Insert employed for adjusting the desired clearance and for adjusting means as wear occurs.

The forward plate of the 611-3-10 Center Member makes contact with the aft surface of the carriage and contains clearance holes for employing cap screws to secure to inserts contained within the carriage aft surface when conducting full (sine) wave shock pulses. When half (sine) wave shock pulses are to be produced these attachment cap screws are removed.

The drawing number 611-2 presents the Carriage and Guide Track system. The Carriage is basically a 6061 aluminum weldment with a "bolt-on" rear plate. The 1.00 inch thick forward test article mounting plate is 48.00 inches by 48.00 inches and contains threaded inserts for fixture attachment. The overall depth of the carriage is 36.00 inches.

The 611-2-18 Guide Bodies are attached to the carriage side surfaces by means of socket head shoulder bolts with four (4) located above and four (4) located below the Guide Tracks. These Guide Bodies contain the brass 611-2-19 Guide Plates which are contained within "close-fitting" rectangular shaped counterbores. The Guide Plates are supported by set screws to permit establishment of desired clearance and to provide adjustment for wear.

The carriage side surfaces contain rectangular shaped counterbores for acceptance of the brass 611-2-25 Guide Plates with four (4) Guide Plates on each side of the carriage. These Guide Plates are supported by set screws to permit establishment of desired clearance and to provide adjustment for wear. The 611-2-23 Carriage Rear Plate must be removed to provide access to these set screws.

When conducting half (sine) wave shock pulses carriage brakes must be employed to produce the relatively low level deceleration or negative pulse which will reduce the velocity to zero as the carriage moves "down" the guide track system. This is accomplished by eight (8) pneumatic operated friction brake assemblies that are attached to the carriage side surfaces by means of socket head shoulder bolts with two (2) assemblies located above and below the Guide Tracks on each side of the carriage. Each 611-2-12 Brake Body contains a primary pneumatic actuator and a redundant pneumatic actuator with two (2) 611-2-17 Brake Pressure Tanks employed with one (1) tank supplying the primary brake circuit and one (1) tank supplying the redundant brake circuit. A common gas pressure source provides the brake pressure to each tank. Therefore the primary and redundant brake pressures are the same and are directed to the brake actuators at the same time. The primary

brake pressure is introduced into the 611-2-12 Brake Body port to thereby act over the top surface of the 611-2-13 Lower Piston which then forces the 611-2-15 Lining Holder downward and forces the 611-2-16 Brake Lining against the guide track surface. This primary brake pressure also acts against the lower surface of the 611-2-11 Upper Piston to force said piston upward against the "shoulder" created by the 611-2-10 Brake Cover. The redundant brake pressure is introduced into the 611-2-10 Brake Cover port to thereby act over the top surface of the 611-2-11 Upper Piston. This top surface area is slightly smaller than the lower surface area and therefore the 611-2-11 Upper Piston remains in its upward position. In the event that the primary brake pressure is "lost" the redundant brake pressure will force the 611-2-11 Upper Piston downward, since the pressure acting over the lower area of said piston is "lost", and transmit said required force through the 611-2-13 Lower Piston to the brake lining. The compression spring located in the chamber below the 611-2-13 Lower Piston retracts the brake lining away from the guide track surface upon removal of the brake pressure(s).

The deceleration or negative level is controlled by the brake pressure employed and generally should be of such

a level so as to allow carriage travel "over" the majority of the guide track length so as to minimize the deceleration phase effect on the test article.

The guide track system basically consists of two (2) tracks located at each side of the carriage with each track composed of five (5) 611-2-20 Guide Track Sections being "joined" at the ends so as to result in a 50 ft. long track system. The 611-2-20 Guide Track Sections are made from steel rectangular tubing with all four (4) sides surface ground so as to have the same size, shape and surface finish. There are twelve (12) Support Stands with six (6) along each track located with one (1) at each end of the track and one (1) at each track section "joint". The intermediate Stands equally span a "joint" and contain attachment bolt as well as registering pins.

With an overall track length of 50 ft. the "useable" track length for both the acceleration and deceleration environments is approximately 41 ft. when considering that the foam barrier at the track end consumes 4 ft. of track length and the carriage; column guide; and initial actuator column extension consume approximately 5 ft. of track length.

The aforementioned available track length is only required when producing half (sine) wave shock pulses and the carriage travel experienced during the deceleration phase can be determined and/or controlled by the following analysis:

1. Determine the maximum velocity achieved during the acceleration phase.

For half sine pulses the formula employed for said determination is

$$\dot{X} = \frac{KG}{W} \quad (2)$$

K = peak acceleration level in G's

G = 386 in./sec./sec.

$$W = \frac{2 \pi}{2 t_f} \text{ and } t_f = \text{pulse duration in seconds}$$

As an example - for a 30 G, 100 ms, half sine the maximum velocity is

$$W = \frac{2(3.14)}{2(.1)} = 31.4$$

$$\dot{X} = \frac{30(386)}{31.4} \quad (2) = 738 \text{ in./sec.}$$

2. The formula employed to determine the deceleration travel for the trapezoidal waveform produced by

the carriage brake system is

$$X = \frac{(X')^2}{2K^1G}$$

K^1 = deceleration level in G's

If one employs a brake pressure which will produce a deceleration level which is 10% of the acceleration level or 3.0 G's the resulting travel experienced during the deceleration phase is

$$X = \frac{(738)^2}{2(3)386} = 235 \text{ inches or } 19.6 \text{ ft.}$$

3. The displacement experienced during the acceleration phase for a half sine shock pulse is determined by the following formula

$$X = \frac{KG}{W} (t_f)$$

For a 30 G, 100 ms, half sine pulse the acceleration displacement is

$$X = \frac{30(386)}{31.4} (.10) = 36.88 \text{ inches}$$

4. Therefore when producing a 30 G, 100 ms, half sine acceleration pulse followed by a 3G deceleration phase the total displacement experienced is 271.88 inches or 22.66 ft..

5. If one desires to minimize the deceleration level by reducing the brake pressure employed and to consume more of the available track length the above equations can be used in the following manner:

Track length to be consumed of say 36 feet or 432 inches.

The available deceleration travel is then 432 inches less the acceleration displacement of 36.88 inches or, say, 395 inches.

The resulting deceleration level to be produced is then

$$K^1 = \frac{(X)^2}{2G X}$$

$$K^1 = \frac{(738)^2}{2(386)395} = 1.79 \text{ G's}$$

6. The specific brake pressure required should be selected on an experience basis but a close approximation can be determined as follows:

The total carriage weight is approximately 1384 pounds and if one employs a total test article weight of say 500 pounds then the weight to be decelerated by the carriage brakes is 1884 pounds.

If the deceleration level is to be 3 G's then the required deceleration force is $3 \times 1884 = 5652$ pounds which is applied by eight (8) brake actuator or then 707 pounds deceleration force per brake actuator.

It can generally be considered that the coefficient of friction of the automotive type brake lining against the steel track surface at the velocities experienced is approximately 0.30.

Consequently the required normal force per brake actuator is

$$F_d = F_N \times C_f$$

$$707 = F_N (0.30)$$

$$F_N = 2357 \text{ pounds}$$

The diameter of the brake actuator piston(s) is 4.00 inches and the resulting effective area is 12.56 sq. in..

Therefore the theoretical brake pressure required

$$\text{is } \frac{2357}{12.56} = \underline{188 \text{ psi}}$$

Section III: Operating Procedures

A. Full Wave Shock Pulses

1. Install the twelve (12) socket head cap screws so as to attach the carriage assembly to the actuator column guide assembly.
2. Introduce electrical power and supply pressure of no less than 500 psi more than the maximum control circuit pressure to be used for a given test and no greater than 3000 psi to the control console.
3. Depress the console Power switch (light on).
4. Establish the required Acceleration Pressure by means of the regulator on the console front panel.
5. Check to make certain that the correct pressures exist at the Retract Pressure, Valve Open Pressure, Valve Close Pressure and Valve Fluid Pressure gauges located on the console front panel.

6. Depress the Retract switch (light on) and wait until the actuator moving element is fully retracted and until the retract pressure gauge "reads" the original pressure setting.
7. Depress the Valve Close switch (light on) and wait for a period of 10 seconds and/or until the valve close pressure gauge "reads" the original pressure setting.
8. Depress the Valve Fluid Pressure switch (light on) and wait for a period of 10 seconds and/or until the valve fluid pressure gauge "reads" the original pressure setting.
9. Depress the Valve Open Pressure switch (light on) and wait for a period of 10 seconds and/or until the valve open pressure gauge "reads" the original pressure setting.
10. With no pressure within the brake pressure circuit (as indicated on the front panel display) depress the Brake Pressure and the Brake

Connector Bypass switches (lights on) and no minimum time period is required.

11. With the proper acceleration pressure indicated on the front panel display - depress the Acceleration Pressure switch (light on) and wait for a period of 3 minutes (180 seconds) and/or until the acceleration pressure display "reads" the original pressure setting and until all retract pressure has been exhausted.
12. When all systems are ready - depress the System Ready switch (light on) to place the machine in a "ready-to-fire" condition and wait for a period of no less than 10 seconds.
13. To conduct the test depress the Test Initiate switch (light on) and continue to depress until the test has been conducted.
14. Following the test and when it is desired to return the carriage to its original position -

depress the System Reset switch. The left light indicates the first phase of reset; the right light indicates the final phase of reset; and when both lights are off and the actuator moving element is fully retracted the reset phase is completed.

15. Depress the Power switch (light off) to remove power from the control circuits.
16. Exhaust the supply pressure input to the control console.

B. Half Wave Shock Pulses

1. Remove the twelve (12) socket head cap screws so as to release the carriage assembly from the column guide assembly.
2. Introduce electrical power and supply pressure of no less than 500 psi more than the maximum control circuit pressure to be used for a given test and no greater than 3,000 psi to the control console.

3. Connect the brake pressure disconnects and the electrical connector to the carriage assembly.
4. Depress the console Power switch (light on)
5. Establish the required Acceleration Pressure by means of the regulator on the console front panel.
6. Establish the required Brake Pressure by means of the regulator on the console front panel.
7. Check to make certain that the correct pressures exist at the Retract Pressure, Valve Open Pressure, Valve Close Pressure and Valve Fluid Pressure gauges located on the console front panel.
8. Depress the Retract switch (light on) and wait until the actuator moving element is fully retracted and until the retract pressure gauge "reads" the original pressure setting.

9. Depress the Valve Close switch (light on) and wait for a period of 10 seconds and/or until the valve close pressure gauge "reads" the original pressure setting.
10. Depress the Valve Fluid Pressure switch (light on) and wait for a period of 10 seconds and/or until the valve fluid pressure gauge "reads" the original pressure setting.
11. Depress the Valve Open Pressure switch (light on) and wait for a period of 10 seconds and/or until the valve open pressure gauge "reads" the original pressure setting.
12. Depress the Brake Pressure switch (light on) and wait for a period of 10 seconds and/or until the front panel display "reads" the original setting.
13. Make certain that the Brake Connector switch is in the off position.

14. With the proper acceleration pressure indicated on the front panel display - depress the Acceleration Pressure switch (light on) and wait for a period of 3 minutes (180 seconds) and/or until the acceleration pressure display "reads" the original setting and until all retract pressure has been exhausted.
15. When all systems are ready - depress the System Ready switch (light on) to place the machine in a "ready-to-fire" condition and wait for a period of no less than 10 seconds.
16. To conduct the test depress the Test Initiate switch (light on) and continue to depress until the test has been conducted.
17. Following the test and when it is desired to return the actuator column to its original position - depress the System Reset switch. The left light indicates the first phase of reset; the right light indicates the final phase of reset; and when both lights are off

and the actuator moving element is fully retracted the reset phase is completed.

18. Exhaust the supply pressure input to the control console.
19. Exhaust the brake pressure from the carriage circuits so as to release the brakes.
20. Depress the "out" switch on the winch control switch station and connect the winch cable to the carriage.
21. Either depress the "in" switch on the winch control switch station or the carriage Return switch on the console front panel to "draw" the carriage back to its original position.
22. Remove the winch cable from the carriage.
23. Depress the Power switch (light off) to remove power from the control circuits.

Section IV: Maintenance

With the subject machine there is basically none of the normally considered maintenance; such as greasing, oiling, etc.; required since the machine is a "closed system" and one which does not operate continuously.

However, it is recommended that the procedures listed below be made as a prevention toward system malfunction that may cause un-timely "shut-down".

The frequency of effecting these procedures depends on the machine useage rate and should be selected by the customer. It is suggested that if the useage rate is "high" then said procedures should be accomplished every one (1) month and if the useage rate is "low" then said procedures should be accomplished every six (6) months.

1. The fluid (water) chamber contained within the actuator 611-4-28 Fluid Chamber (middle) Cylinder should be purged and filled to ensure minimal air entrapment.

The actuator moving element should be moved outwardly and fully extended so as to cause contact between the

611-4-96 Support Piston and the 611-4-30 Fluid Orifice Plate. This can be accomplished by the introduction of 100 psi "plant air" into the port contained within the 611-4-26 Orifice Plate which is directed toward the forward surface of said orifice plate. The actuator valve should be closed at this time by the introduction of a valve close pressure which is equal to or greater than the aforementioned "plant air" input pressure.

There are two (2) ports contained within the aft end of the 611-4-34 Forward Cylinder with said ports being at the top and bottom of said cylinder.

With the top port closed - connect the fluid (water) input line to the bottom port. Open the top port and introduce fluid until a "clear" pure fluid stream discharges from the top port. Shut-off the fluid supply; close the top port; and remove the fluid in-out line.

An appropriate amount of rust inhibitor should exist in the fluid chamber.

2. The fluid (water) chamber within the actuator valve; the associated accumulator which exists within the control console; and the inter-connecting line should be purged and filled to ensure minimal air entrapment.

The valve should be placed in a fully open position by the introduction of no less than 100 psi and no greater than 500 psi valve open pressure. This pressure can be introduced through the control console valve open pressure circuit or can be introduced into the port located in the 611-4-26 Orifice Plate which is identified by the metal stamp "VOP".

The fluid source line, which can be from a plant water source, should be connected to the fitting provided at the console outlet located between the solenoid valve at the accumulator fluid end and the actuator valve.

The port located in the 611-4-26 Orifice Plate which is identified by the metal stamp "AB" should be opened to the atmosphere.

The water should be introduced until a "clear" pure fluid stream discharges from the "AB" port. Close the water input line and close the "AB" port.

Remove the tubing line and fitting from the gas end of the control console accumulator.

Remove all gas pressure to the console circuits by setting all circuits regulators for zero circuit pressure.

Open the water source line and depress the console switches in the normal operating sequence so as to allow power to the Test Initiate switch.

Remove the fitting cap located at the top of the accumulator at the fluid end.

Depress the Test Initiate switch until a "clear" pure fluid stream discharges from the accumulator fitting mentioned above.

With the Test Initiate switch de-energized replace the accumulator fitting cap.

Depress the Test Initiate switch to allow water to enter the accumulator until the accumulator piston has been moved completely to the gas end which can be "seen" through the open end port.

Close and remove the water source input line.

Re-connect the accumulator gas end fitting and tubing.

De-energize all console switches by depressing the Reset switch.

Introduce gas supply pressure to the console and set the Valve Fluid Pressure regulator at 100 psi circuit pressure.

Open the "AB" port at the 611-4-26 Orifice Plate and prepare to meter water into a measured container.

Depress the console switches in a normal operating manner until the Valve Fluid Apply switch is energized.

At the "AB" port remove between $\frac{1}{2}$ pint and 1 pint of water.

Close the "AB" port; remove the valve fluid pressure;
and de-energize all switches.

3. It is recommended that a liberal coating of either Lithium base or Graphite base grease be applied to the extended 611-4-42 Main Column following a test and prior to initiating the reset and retract operations as determined necessary upon visual inspection of the column surface.

Section V: Assembly Procedures

This section is devoted to describing the assembly and dis-assembly procedures pertaining to changing the Metering Column employed and to installation of spare seals within the actuator valve since these are the only areas of the subject system which normally should require such activity.

A. The following procedures should be employed for changing the Metering Column:

1. Remove the forward end support structure from the 611-4-40 Forward Cover and move said structure away from the Forward Cover a "few feet" to allow "working room".
2. Remove the support structure "band" which surrounds the 611-4-30 Fluid Orifice Plate.
3. Make certain that the required "alignment reference points" are known so as to assure that the actuator forward and middle chambers assembly can and will be replaced in exactly the existing position.

4. Remove the twelve (12) 1½-6NC by 5 inch long cap screws which attach the 611-4-28 Fluid Chamber Cylinder aft flange to the 611-4-26 Orifice Plate.
5. With "lifting slings" around the 611-4-34 Forward Cylinder and around the 611-4-28 Fluid Chamber Cylinder attached to an overhead crane or similar device, which are all capable of safely lifting approximately 10,000 pounds, move the 611-4-28 Fluid Chamber Cylinder away from and dis-engage the 611-4-26 Orifice Plate.
6. Place this entire cylinder assembly in a verticle position with the 611-4-28 Fluid Chamber Cylinder aft flange downward and on the "floor".
7. Either attach the Fluid Chamber Cylinder aft flange to the "floor" and/or employ cables or chains from the forward end of the 611-4-28 Fluid Chamber Cylinder to the "floor" to make certain that this cylinder assembly is secured vertically and is "safe".

8. Remove the 611-4-41 Column Forward Flange from the 611-4-42 Main Column.
9. Remove the twelve (12) $1\frac{1}{4}$ -7NC by $5\frac{1}{2}$ in. long cap screws which attach the 611-4-40 Forward Cover to the 611-4-38 Flange.
10. Remove the 611-4-40 Forward Cover from the 611-4-42 Main Column and the 611-4-34 Forward Cylinder.
11. Attach a lifting "mechanism" to the 611-4-38 Flange and remove all "slack".
12. Remove the twelve (12) $1\frac{1}{4}$ -7NC by 5 inch long cap screws which attach the 611-4-31 Flange to the 611-4-30 Fluid Orifice Plate.
13. Lift the 611-4-34 Forward Cylinder away from and dis-engage the 611-4-30 Fluid Orifice Plate; the 611-4-32 Separator Piston; and the 611-4-42 Main Column.
14. Replace the 611-4-41 Column Forward Flange on the 611-4-42 Main Column for full thread engagement.

15. Attach a lifting "mechanism" to the 611-4-41 Column Forward Flange and remove all "slack".
16. Connect a flexible hose to the port that exists in the 611-4-30 Fluid Orifice Plate which is directed toward the fluid (water) chamber.
17. Apply an upward lifting load to the 611-4-42 Main Column so as to raise the entire actuator moving element and discharge the water through the flexible hose into an appropriate "reservoir".
18. When the 611-4-96 Support Piston has made or is about to make contact with the 611-4-30 Fluid Orifice Plate discontinue all upward lifting action and hold that position.
19. Remove the twelve (12) $1\frac{1}{2}$ -6NC by 5 in. long cap screws which attach the 611-4-29 Flange to the 611-4-30 Fluid Orifice Plate.
20. Continue the upward lifting action so as to disengage the 611-4-30 Fluid Orifice Plate from the 611-4-28 Fluid Chamber Cylinder and to disengage the 611-4-27 Piston from the 611-4-28 Fluid Chamber Cylinder.

21. Place the actuator moving element assembly in a convenient and clean working area.
22. Loosen the set screw contained in the 611-4-32 Separator Piston and remove the Separator Piston and the Main Column assembly from the Metering Column by un-threading counter-clockwise.
23. Loosen the set screw contained in the 611-4-96 Support Piston and remove the Metering Column from the Support Piston by un-threading counter-clockwise with a "strap wrench" employed on the Metering Column.
24. Remove the cap screws which attach the 611-4-98 Flange to the 611-4-96 Support Piston and remove the Support Piston from the 611-4-97 Separator Column.
25. Remove the 611-4-97 Separator Column from the 611-4-45 Piston Stud by un-threading counter-clockwise with a "strap-wrench" on the Separator Column.

26. After selection of the appropriate and desired Metering Column/Separator Column assembly and when it is desired to re-assemble the actuator remove the pipe plug which exists at the aft surface of the 611-4-27 Piston and make certain that the 611-4-45 Piston Stud is fully "bottomed" in the Piston.

If further engagement is required then loosen the set screw in the Piston and thread the Stud inward as required by means of pins and a bar in the end holes provided. Then tighten the Piston set screw.

Place teflon tape on the pipe plug and replace in the Piston aft surface port.

27. When assembling the Separator Column to the Piston Stud it will be necessary to make certain that the Separator Column is fully bottomed in the 611-4-27 Piston. Therefore measure the depth of the Piston 'O' ring counterbore and place a scribe mark on the Separator Column at this measured distance from its aft end.

Place a small amount of grease on the Piston 'O' ring and oil on the Separator Column aft end.

Place oil on the 611-4-45 Piston Stud threads.

Thread the Separator Column onto the Piston Stud slowly since both ports are aluminum and fully engage the 611-4-27 Piston 'O' ring and counterbore until "bottom is felt" and/or until the aforementioned scribe mark aligns with the Piston top surface.

28. Clean all surfaces of the Support Piston and the Metering Column.

Place a small amount of grease on the 'O' ring contained within the Support Piston counterbore; place oil on the Metering Column threads; make certain that the Piston set screw is loosened; and remove the pipe plug which exists at the Support Piston aft surface counterbore.

Thread the Metering Column slowly into the Support Piston until "bottom" is felt and/or until it can

be seen, through the pipe plug hole, that the Metering Column thread end is fully bottomed in the Support Piston.

Place teflon tape on the pipe plug and install in the Support Piston aft surface making certain that the pipe plug finishes below the Support Piston counterbore surface.

Tighten the Support Piston set screw.

29. Place oil on the top end of the Separator Column and within the Support Piston counterbore.

Install the Support Piston aft surface counterbore on the Separator Column shoulder.

The 611-4-98 Flange should be positioned on the Separator Column such that when the ports are fully engaged approximately 1/16 in. space exists between the Flange and the Support Piston.

Install the cap screws and tighten evenly until full engagement is achieved with lock washers and safety wires employed.

30. Clean the 611-4-30 Fluid Orifice Plate; check 'O' rings and replace as required; and place the Orifice Plate, with beveled surface downward, over the Metering Column and onto the Support Piston.

31. Measure the depth of the 'O' ring counterbore in the aft surface of the 611-4-32 Separator Piston and place a scribe mark on the top end of the Metering Column at said measured distance.

Oil the Piston counterbore 'O' ring and the end of the Metering Column. Make certain that the Piston set screw is loosened.

Thread the Separator Piston slowly onto the Metering Column until fully bottomed and/or until the aforementioned scribe mark aligns with the aft surface of the Separator Piston.

Tighten the Piston set screw.

32. Clean all surfaces of the assembly; make certain that all exposed seal rings are proper; coat the

outer surfaces of the pistons with grease; and coat the Main Column surface with oil.

Make certain that the bore of the 611-4-28 Fluid Chamber Cylinder is clean and coat with oil by pouring around sides of bore upper end.

33. By lifting with the 611-4-41 Column Forward Flange place the 611-4-27 Piston; the 611-4-96 Support Piston; and the 611-4-30 Fluid Orifice Plate into the 611-4-28 Fluid Chamber Cylinder.

Make certain that the Fluid Orifice is positioned to properly locate the threaded holes.

34. Replace the cap screws which attach the 611-4-29 Flange to the 611 4-30 Fluid Orifice Plate.

35. Make certain that the bore of the 611-4-34 Forward Cylinder is clean; liberally coat with oil by pouring around the top of the bore; and fill the inside of the two (2) lower end pipe ports with grease.

36. By lifting with the 611-4-38 Flange place the 611-4-34 Forward Cylinder over the Main Column; the Separator Piston; and onto the Fluid Orifice Plate.

Make certain that the Forward Cylinder is positioned so as to have the aforementioned pipe ports at the top and bottom of the actuator when placed horizontally in position.

37. Replace the cap screws which attach the 611-4-31 Flange to the 611-4-30 Fluid Orifice Plate.
38. Remove the 611-4-41 Column Forward Flange from the 611-4-42 Main Column.
39. Make certain that all surfaces of the 611-4-40 Forward Cover are clean; that all 'O' rings are proper; liberally coat the inner 'O' ring and the 611-4-39 Bushing with grease; and coat the outer 'O' ring with grease.
40. Place the Forward Cover onto the Main Column and into the 611-4-34 Forward Cylinder.

Make certain that correct orientation exists for proper port alignment.

41. Replace the cap screws which attach the Forward Cover to the 611-4-38 Flange.
42. Replace the 611-4-41 Column Forward Flange onto the Main Column.
43. Place the entire assembly horizontally.
44. Make certain that the 611-4-26 Orifice Plate is clean on all surfaces and place grease on the exposed 'O' ring.
45. Engage the 611-4-28 Fluid Chamber Cylinder onto the 611-4-26 Orifice Plate and replace the cap screws which attach these parts.

Make certain that the entire assembly is in its proper and original alignment before final tightening of the cap screws between the Cylinder and the Orifice Plate.

46. Replace all remaining components to their original condition.

B. The following procedures should be employed for replacing any actuator valve components:

1. Disconnect the forward end support structure from only the floor base structure and the two (2) guide tracks.
2. Disconnect the 611-4-30 Fluid Orifice Plate support structure from the floor.
3. Make certain that the required "alignment reference points" are known so as to assure that the entire actuator assembly can and will be replaced in exactly the existing position.
4. Remove the twelve (12) 1½-6NC by 5 inch long cap screws which attach the 611-4-28 Fluid Chamber Cylinder aft flange to the 611-4-26 Orifice Plate.
5. With "lifting slings" around the 611-4-34 Forward Cylinder and around the 611-4-26 Fluid Chamber

Cylinder attached to an overhead crane or similar device, which are all capable of safely lifting approximately 10,000 pounds, move the 611-4-28 Fluid Chamber Cylinder away from and dis-engage the 611-4-26 Orifice Plate only a "few inches" and move the two (2) support structures along with this assembly.

Place a support under the 611-4-28 Fluid Chamber Cylinder aft end and release this assembly from the lifting unit.

6. Place lifting straps around the 611-4-12 Rear Cylinder and connect to a lifting "unit" which all have a safe lifting capacity of approximately 8,000 pounds.
7. Remove the 1½-6NC cap screw which connect through the reaction structure into the 611-4-10 Rear Cover from the rear of the reaction structure.
8. Lift the entire rear chamber assembly upward and away from the reaction structure.

9. Place this assembly with the 611-4-26 Orifice Plate downward on a wood support surface.
10. Remove the twenty-four (24) $1\frac{1}{2}$ -6NC by 6 in. long cap screws which attach the 611-4-11 Rear Cylinder Flange to the 611-4-26 Orifice Plate.
11. Lift the Rear Cylinder and Rear Cover upward and away from the actuator valve assembly.
12. Remove the tubes connected to the 611-4-15 Valve Rear Cylinder, the 611-4-13 Valve Rear Cover and the 611-4-18 Valve Orifice.
13. Remove the twelve (12) 1-8NC by 5 $\frac{3}{4}$ in. long cap screws which attach the 611-4-14 Valve Flange to the 611-4-19 Valve Flange.
14. Lift the 611-4-15 Valve Rear Cylinder and the 611-4-13 Valve Rear Cover away from the 611-4-18 Valve Orifice and the valve moving element assembly.
15. Withdraw the valve moving element assembly; which

consists of the Valve Lock Nut, the Valve Seal Piston, the Valve Connecting Rod, the Valve Flow Restrictor and the Valve Piston; from the 611-4-21 Valve Forward Cylinder and allow the 611-4-18 Valve Orifice to move with this assembly.

When performing this operation take particular care to lift the assembly straight upward and in-line with the cylinder so as to not damage the bonded rubber seal on the forward end of the Valve Piston.

16. Loosen the set screw in the 611-4-16 Valve Lock Nut and un-screw the Lock Nut from the 611-4-20 Valve Connecting Rod.
17. Un-screw the 611-4-17 Valve Seal Piston from the Valve Connecting Rod.
18. Remove the 611-4-25 Valve Flow Restrictor, which is a sliding fit, from the Valve Connecting Rod.
19. Remove the 611-4-18 Valve Orifice.

20. Loosen the set screw in the 611-4-22 Valve Piston and remove the 611-4-20 Valve Connecting Rod from the Valve Piston.

21. Clean all valve parts thoroughly.

22. If the spare Valve Piston and the spare Valve Seal Piston are to be installed then place new 'O' rings on and in the 611-4-22 Valve Piston.

Place a light film of grease on the 'O' ring which seals to the Valve Connecting Rod.

Remove the teflon plug and set screw from the original Valve Piston and install in the spare Piston.

23. The Valve Connecting Rod has the same size threads at each end but the thread lengths are different. The longer thread length end engages the 611-4-22 Valve Piston.

Place a film of oil on the Valve Connecting Rod end and oil on the longer threaded end.

Thread the Valve Connecting Rod into the Valve Piston fully by clamping the Rod in vise soft jaws and using a strap wrench on the Piston.

Tighten the Piston set screw.

24. The 611-4-18 Valve Orifice has two pipe ports wherein one (1) port is straight and one (1) is directed toward an end surface. This port end surface should be away from the Valve Piston.

Place the Valve Orifice over the Connecting Rod and onto the Valve Piston with the pressure port away from the Valve Piston.

25. Place a film of oil on the Connecting Rod surface and place the Valve Flow Restrictor over the Connecting Rod with the smaller diameter end toward the Valve Piston.

26. Place a light film of grease on the 611-4-17 Valve Seal Piston inner 'O' ring which engages the Connecting Rod and oil on the Connecting Rod and threads.

Screw the 611-4-17 Valve Seal Piston onto the Connecting Rod fully until "contact" is made between the Valve Piston, Flow Restrictor and Seal Piston.

27. Place oil on the Connecting Rod threads and screw the 611-4-16 Valve Lock Nut onto the Connecting Rod and "firmly" against the Seal Piston.

Tighten the Lock Nut set screw.

28. Liberally coat all inner surfaces of the 611-4-23 Separator Plate and the 61 -4-21 Valve Forward Cylinder with oil.

Liberally coat the outer surfaces of the Valve Piston with grease.

Install the Valve Piston into the Valve Forward Cylinder and the Separator Plate making certain to move the Piston in-line with the engaging surfaces and take particular care not to damage the bonded seal ring in the Valve Piston.

29. Engage the 611-4-18 Valve Orifice evenly into the Valve Forward Cylinder and align the two (2) fittings to properly engage the tubes from the 611-4-26 Orifice Plate.

Engage these tubes on the fittings and tighten the fitting nuts firmly.

The port which is straight in the Valve Orifice is connected to the VFP fitting in the 611-4-26 Orifice Plate and the port which directed toward the Valve Seal Piston is connected to the VB fitting in the Orifice Plate.

30. Liberally coat the outer surface of the Valve Seal Piston with grease and particularly fill the outer 'O' ring groove with grease around the 'O' ring.

Liberally coat the bore of the 611-4-15 Valve Rear Cylinder with grease and particularly fill the inside surface of the cylinder wall port hole with grease.

Place the Valve Rear Cylinder down and over the Valve Orifice.

Make certain to align the fittings with the tubes from the 611-4-26 Orifice Plate. The fitting in the Valve Rear Cylinder should be connected to the VP (or possibly termed AB) fitting in the 611-4-26 Orifice Plate and the fitting in the Valve Rear Cover should be connected to the VCP fitting in the Orifice Plate.

Engage these tubes on the fittings and tighten the fitting nuts firmly.

31. Install the cap screws which attach the 611-4-14 Valve Flange to the 611-4-19 Valve Flange and tighten evenly.
32. Clean all remaining surfaces and replace the 'O' ring on the 611-4-26 Orifice Plate if required.

Coat this 'O' ring with grease.

33. Coat the lower end of the 611-4-12 Rear Cylinder bore with grease and replace the Rear Cylinder/Rear Cover assembly over the valve and engage the

Orifice Plate making certain that proper orientation exists.

34. Replace the cap screws which attach the 611-4-11 Rear Cylinder Flange to the Orifice Plate.
35. Finish assembly of the actuator by simply reversing the dis-assembly procedures taking care to ensure original alignment.

Section VI: Parts List and Recommended Spare Parts

A. Actuator Manufactured Parts

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	1	611-4-10 Rear Cover
2	2	611-4-11 Rear Cylinder Flange
3	1	611-4-12 Rear Cylinder
4	1	611-4-13 Valve Rear Cover
5	3	611-4-14 Valve Flange
6	1	611-4-15 Valve Rear Cylinder
7	1	611-4-16 Valve Lock Nut
8	1	611-4-17 Valve Seal Piston
9	1	611-4-18 Valve Orifice
10	1	611-4-19 Valve Flange
11	1	611-4-20 Valve Connecting Rod
12	1	611-4-21 Valve Forward Cylinder
13	1	611-4-22 Valve Piston
14	1	611-4-23 Separator Plate
15	1	611-4-24 Valve Port Cylinder
16	1	611-4-25 Valve Flow Restrictor
17	1	611-4-26 Orifice Plate
18	1	611-4-27 Piston
19	1	611-4-28 Fluid Chamber Cylinder
20	2	611-4-29 Flange

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
21	1	611-4-30 Fluid Orifice Plate
22	1	611-4-31 Flange
23	1	611-4-32 Separator Piston
24	1	611-4-33 Column Flange
25	1	611-4-34 Forward Cylinder
26	2	611-4-35 Exhaust Valve Cylinder
27	16	611-4-36 Shoulder Stud
28	2	611-4-37 Valve Seal Piston
29	1	611-4-38 Flange
30	1	611-4-39 Bushing
31	1	611-4-40 Forward Cover
32	1	611-4-41 Column Forward Flange
33	2	611-4-43 Actuator Support Stand
34	1	611-4-42 Main Column
35	various	611-4-95 Metering Column
36	1	611-4-96 Support Piston
37	various	611-4-97 Separator Column
38	1	611-4-98 Flange

B. Actuator Purchased Parts

Refer to drawing number 611-4

C. Carriage and Track System Manufactured Parts

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	8	611-2-10 Brake Cover
2	8	611-2-11 Upper Piston
3	8	611-2-12 Brake Body
4	8	611-2-13 Lower Piston
5	8	611-2-14 Cover Plate
6	8	611-2-15 Lining Holder
7	8	611-2-16 Brake Lining
8	2	611-2-17 Brake Pressure Tank
9	8	611-2-18 Guide Body
10	8	611-2-19 Guide Plate
11	10	611-2-20 Guide Track Section
12	12	611-2-21 Support Stand
13	1	611-2-23 Carriage Rear Plate
14	1	611-2-24 Carriage Body
15	8	611-2-25 Guide Plate

D. Carriage and Track System Purchased Parts

Refer to drawing number 611-2

E. Column Guide Manufactured Parts

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	1	611-3-10 Center Member
2	2	611-3-11 Guide Side Plate
3	4	611-3-12 Guide Plate
4	6	611-3-13 Guide Insert

F. Column Guide Purchased Parts

Refer to drawing number 611-3

G. Miscellaneous Manufactured Parts

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	1	611-6 Actuator Mounting and Reaction Structure
2	1	611-7 Foam Barrier Housing

H. Control System Purchased Parts

Refer to drawing number 611-5 for the system schematic.

Refer to drawing number 611-9 for the system wiring diagram.

Refer to drawing number 611-5-10 for the control console panel.

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	lot	Console cabinet consisting of the following parts manufactured by G.F. Business Equipment Inc. (formerly Ingersall Products - Emcor), Rochester, Minnesota: (1) SFR-272A Frame (1) SSP-70A-FL-LH Panel (1) SSP-70A-FL-RH Panel (2) SSP-62A-FL Panel (2) SSP-105A Panel (1) PN-14-24 Panel (1) PN-19-24 Panel (1) PN-7F-24 Panel (1) set HW-484 Casters (2) D021D-24-LH Door

Item

Qty.

Description

Note: All parts except PN-7F-24
are EN-2BU Blue and the Table
Panel PN-7F-24 is 1480-N White

2

1

P/N 50 PM3-152G-2 Digital Panel
Pressure Indicator with P/N 406-
1500G-37 Pressure Transducer -
Consolidated Controls Corp.
Bethel, Connecticut

3

1

P/N 50PM3-302G-2 Digital Panel
Pressure Indicator with P/N 406-
300G-37 Pressure Transducer -
Consolidated Controls Corp.
Bethel, Connecticut

4

1

Grove Regulator Co. Model 94-P/N
11486F2A "Mity-Mite" Dome Regulator
(DR)

5

2

Standard Pneumatic Engineering Co.,
Hemet, Calif. - P/N LC350-98
Regulator (R1 & R2)

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
6	2	Standard Pneumatic Engineering Co., Hemet, Calif. - P/N LC 100-98 Regulator (R4 & R5)
7	1	Standard Pneumatic Engineering Co., Hemet, Calif. - P/N LC 2000-98 Regulator (R3)
8	1	Standard Pneumatic Engineering Co., Hemet, Calif. - P/N LC 3000-98 Regulator (R6)
9	2	Circle Seal Corp., Anaheim, Calif.- P/N M 5159B - 2M-286-345 Relief Valve
10	1	Circle Seal Corp., - P/N M 5159B- 2M-1401-1900 Relief Valve
11	2	Circle Seal Corp. - P/N M 5159B- 2M-1000-1200 Relief Valve
12	1	Circle Seal Corp. - P/N M 5159B- 2M-1901-2400 Relief Valve

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
13	2	U.S. Gauge Co. - P/N P844U, Spec. #138018, 2½ in., 0-400 psi Gauge
14	2	U.S. Gauge Co. - P/N P500, Spec. #46994, 2½ in., 0-3000 psi Gauge
15	1	U.S. Gauge Co. - P/N P844U, Spec. #138020, 2½ in., 0-1000 psi Gauge
16	1	U.S. Gauge Co. - P/N P844U, Spec. #138021, 2½ in., 0-2000 psi Gauge
17	1	Circle Seal Corp. Anaheim, Calif. P/N SV31A2NC4P Solenoid Valve (NCSV14)
18	2	Atkomatic Valve Co., Indianapolis, Indiana - P/N 15420 Solenoid Valve (NCSV2 & NCSV12)
19	1	Atkomatic Solenoid Valve P/N 521 (NOSV1)

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
20	1	Atkomatic Solenoid Valve P/N 15400 (NCSV3)
21	2	Atkomatic Solenoid Valve P/N 3001 (NOSV6 & NOSV13)
22	5	Atkomatic Solenoid Valve P/N 6100 (NCSV4, NCSV5, NCSV7, NCSV10 & NCSV11)
23	1	Atkomatic Solenoid Valve P/N 6101 (NOSV8)
24	1	Atkomatic Solenoid Valve P/N 8104 (NCSV9)
25	1	DeLaval-Barksdale Controls, Los Angeles, Calif. - P/N C9612-2 Pressure Switch (PS)
26	3	Allied-Witan Co., North Royalton, Ohio. - P/N P07PH Muffler
27	1	Parker-Hannifan Co., Cleveland, Ohio - P/N A4A0058BIK Accumulator

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
28	1	Parker-Hannifan Co., Cleveland, Ohio - P/N A2A0010AIK Accumulator
29	3	Master Specialties Co., Costa Mesa, Calif. - P/N 12-51 Switches
30	9	Master Specialties Co. P/N 90EA1C2J 1RL1N1R Switches
31	9	Potter-Brumfield Latching Relay P/N KBP17AG
32	2	General Time P/N 2111-IPF-160 Timer
33	1	Thern Winch Co. P/N 453A5 Winch
34	1	Allen-Bradley P/N 705-AAA Starter

I. Recommended Spare Parts.

<u>Item</u>	<u>Qty.</u>	<u>Description</u>
1	1	P/N611-4-17 Valve Seal Piston
2	1	P/N 611-4-22 Valve Piston
3	1	P/N 611-4-39 Bushing
4	1	P/N 611-4-42 Main Column
5	8	P/N 611-2-16 Brake Lining
6	3	Complete set of seal rings

Section: VII: Performance Determination and Analysis

The subject Shock System has the ability to produce either half wave shock pulses and/or full wave shock pulses. The half wave shock pulses consist of a primary acceleration shock pulse followed by a low level deceleration phase which has a level which normally is 10% of the peak acceleration level with the deceleration waveform being trapezoidal or relatively constant level. The half wave acceleration phase can be of any waveform desired which is within the response capability of the fluid metering system. The full wave shock pulses simply consist of an acceleration phase immediately followed by a deceleration phase with either the same waveform or with different wave forms which "fit within" the force, velocity-change, and stroke capabilities of the machine.

The maximum stroke capability of the machine is 136.00 inches. A portion of this stroke is consumed by a "pulse ending shoulder" and therefore it should be considered that the useable maximum stroke capability for full wave shock pulses is approximately 123.00 inches and the useable maximum stroke capability for half wave shock pulses is approximately 80.00 inches.

The machine was originally constructed to produce both half sine and full sine wave shock pulses. The equations of motion for said waveforms are as follows:

1. Half Sine

$$X \text{ (acceleration)} = KG \sin W't$$

K = peak level in G's

G = 386 in/sec/sec.

$$W' = \frac{360^\circ}{T}$$

T = full sine wave period in seconds

t = time in seconds at which acceleration
is to be determined

$$\dot{X} \text{ (velocity)} = \frac{KG}{W} (1 - \cosine W't)$$

$$X \text{ (displacement)} = \frac{KG}{W} \left(t - \frac{\sin W't}{W} \right)$$

$$W = \frac{6.28}{T}$$

2. Full Sine

The functions during the first half sine wave are determined by 1. above.

The functions during the second or final half sine wave are determined by:

$$\ddot{X} \text{ (deceleration)} = K_2 G \sin W' t_2$$

K_2 = peak deceleration level in G's

t_2 = time within the deceleration phase at
which level is to be determined

$$\dot{X} = \dot{X}_0 - \frac{K_2 G}{W} (1 - \cos W' t_2)$$

$\dot{X}_0$ = velocity at end of acceleration phase

$$X = \dot{X}_0 t_2 - \frac{K_2 G}{W} \left(t_2 - \frac{\sin W' t_2}{W'} \right)$$

The effective area of the main piston aft surface is 181.844 square inches and the normal maximum acceleration (gas) pressure employed is 2,000 psi. Therefore the normal maximum static output force capability is 363,688 pounds.

The dynamic force capability and therefore the shock level capability are a function of the pulse stroke, the pulse velocity, and the total mass or weight involved.

The system "tare weight" or weight excluding the test article is approximately 3,400 pounds. The actual effective weight is governed by the Metering Column contour and the quantity of fluid involved.

The diameter of the cylinder bores is 15.220 inches. The primary diameter of the fluid metering orifice passageway is 8.875 inches. The diameter of the gas input passageway is 8.000 inches. The gas volume of the acceleration pressure chamber is 20,204 cubic inches.

When determining the instantaneous effective gas pressure the expansion process is adiabatic and therefore the expression of $P_1 V_1^{1.4} = P_2 V_2^{1.4}$ must be employed.

When the valve, contained within the acceleration pressure chamber, is opened to release the high pressure gas a volume change occurs which increases the aforementioned 20,204 cubic inches by 590 cubic inches.

When the acceleration shock pulse initiates the fluid chamber pressure must be of a level which produces a negative force which equals the acceleration pressure positive force. During this phase the fluid pressure effective piston area is 120.01 square inches. This condition is effected by the actuator moving element assembly moving forward and thereby compressing the fluid chamber from zero pressure to that required. The amount of piston motion involved is a function of the fluid pressure required and the

fluid quantity. The piston motion can be determined in the following manner:

Example:

Initial Acceleration Pressure = 1200 psi

Fluid Quantity = 11,500 cubic inches

Acceleration Pressure when valve is opened:

$$P_2 = \frac{1200 (20,204)^{1.4}}{(20,794)^{1.4}} = 1153 \text{ psi}$$

Resulting positive force:

$$1153 (181.844) = 209,666 \text{ pounds}$$

Resulting required fluid pressure:

$$\frac{209,666}{120.01} = 1747 \text{ psi}$$

Resulting fluid strain:

$$\epsilon = \frac{1747}{300,000} \text{ psi} = .00582 \text{ in./in.}$$

Resulting fluid volume change:

$$.00582 (11500) = 66.97 \text{ cu. in.}$$

Resulting piston motion:

$$\frac{66.97}{120.01} = \underline{0.558} \text{ inches.}$$

In most cases the Metering Column will contain an initial shoulder length of 2.375 inches and the shock pulse will initiate following said displacement. Therefore the initial Acceleration Pressure must be determined on the basis of an additional volume increase of 181.844 (2.375) = 432 cu. in..

One must then determine the shock level, velocity, and displacement for the pulse to be produced.

The Acceleration Pressure must be selected and the instantaneous pressures determined at specific time periods within the shock pulse. This instantaneous pressure times the piston area of 181.844 sq. in. then gives the instantaneous positive force.

With the corresponding instantaneous acceleration and/or deceleration levels known and the total weight known one then knows the required instantaneous output force - either positive or negative.

From this one can then determine the required instantaneous fluid pressure based on an initial effective

fluid pressure area of 120.01 sq. in..

The following equation can be employed to determine the required instantaneous fluid flow area:

$$\Delta P = \left[\frac{X' A_p}{109 A_f} \right]^2$$

ΔP = fluid pressure (psi)

X' = piston velocity (in./sec.)

A_p = piston area (sq. in.)

A_f = fluid flow area (sq. in.)

It is important to realize that the fluid pressure instantaneous effective area is the area from the diameter of the Metering Column, which is determined by solving for A_f above, to the cylinder bore of 15.200 inches. Therefore once an initial A_f is determined and the resulting Metering Column diameter determined by knowing that the fluid orifice passageway diameter is 8.87 inches, the piston area (A_p) must be corrected; the required fluid pressure (P) must be corrected; and a revised or corrected fluid flow area (A_f) determined. This correction process must be continued until the resulting Metering Column diameter is within normal machining tolerances during the last two (2) correction processes.

When a Metering Column contour is known it must be determined if the minimum diameter is capable of transmitting the applied positive and/or negative shock force. The Metering Column is normally made from 6051-T6 Aluminum and it is considered that the normal maximum desired compressive and/or tensile stress induced is 9,000 psi. If it is determined that the induced stress is greater than 9,000 psi then the Metering Column diameters must be increased by increasing the Acceleration Pressure employed.

In most cases the Acceleration Pressure gas pressure drop through the 8,000 inch diameter passageway is a negligible amount. However, it is advised that this be checked at the maximum shock pulse velocity by using the formula:

$$\Delta P = P_1 \left[\frac{X A_p}{16,500 A_f} \right]^2$$

P_1 = instantaneous Acceleration Pressure

X = piston velocity

A_p = piston area = 181.844 sq. in.

A_f = gas flow area = 50.24 sq. in.

The original tests conducted with the subject Shock System resulted in the following conclusions:

1. The acceleration shock waveform was as desired when employing the equations stated herein.
2. When conducting 30G - 100 ms half sine duration tests the deceleration waveform level exceeded that desired with a resulting time period being less than desired.

This condition was and is contributed to the fact that the fluid condition changes between accelerating and decelerating the fluid body such that the formulas stated herein are not perfectly correct for determining the Metering Column contour for the deceleration phase.

3. Transients, in the form of both high and low frequency vibrations, were experienced primarily during the deceleration phase which are the result of both cavitation and traveling waves being experienced within the fluid body.